Astronomy and Astrology in India and Iran

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ONLY in recent years have the interrelationships of Babylonian, Greek, and Indian astronomy and astrology become a subject which can be studied meaningfully. This development is due to several factors: our greatly increased understanding of cuneiform material made possible by the scholarship of Professor O. Neugebauer; [1] the discovery of Babylonian parameters and techniques not only in the standard Greek astronomical texts,[2] but in papyri and astrological treatises as well; and the finding of Mesopotamian material in Sanskrit works and in the traditions of South India. Unfortunately, a lack of familiarity with the Sanskrit sources and a failure to consider the transmission of scientific ideas in the context of a broad historical perspective have recently led one scholar to the erroneous conclusion that Sasanian Iran played a crucial role in the introduction of Greek and Babylonian astronomy and astrology to India and in the development of Indian planetary theory.[3] It is my purpose in this paper to survey briefly the influence of foreign ideas on Indian gaṇakas so as to make clear the creative use they made of their borrowings in devising the yuga-system of astronomy; and then to examine the character of Sasanian astronomy and astrology, pointing out their almost complete lack of originality.

The earliest Indian texts which are known — the Vedas, the Brâhmaṇas, and the Upaniṣads — are seldom concerned with any but the most obvious of astronomical phenomena; and when they are so concerned, they speak with an obscurity of language and thought that renders impossible an adequate exposition of the notions regarding celestial matters to which their authors subscribed. One may point to the statement that the year consists of 360 days as a possible trace of Babylonian influence in the Ṛgveda,[4] but there is little else which lends itself to a similar interpretation. It has often

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1 See especially his *Astronomical Cuneiform Texts*, 3 vols., London, 1955 (hereafter *ACT*), and *The Exact Sciences in Antiquity*, 2nd ed., Providence, R. I., 1957, chap. 5 (hereafter *Exact Sciences*).

2 See A. Aaboe, "On the Babylonian Origin of Some Hipparchan Parameters," *Centaurus*, 1955-1956, *4*: 122-125, and Neugebauer, *Exact Sciences*, pp. 157, 183. The basic survey of the transmission of astronomy is O. Neugebauer, "The Transmission of Planetary Theories in Ancient and Medieval Astronomy," *Scr. Math., N. Y.*, 1956, *22*: 165-192.

3 B. L. van der Waerden, *Vjschr. Naturf. Ges. Zürich*, 1960, *105*: 140-143.

4 On the Vedic year, see G. Thibaut, *Astronomie, Astrologie und Mathematik*, Grundriss der Indo-Arischen Philologie und Altertumskunde 3, 9, Strassburg, 1899, pp. 7-9.

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been proposed, of course, that the list of the twenty-eight nakṣatras which is given for the first time at the beginning of the last millennium before Christ in the Atharvaveda and in various Brâhmaṇas is borrowed from Mesopotamia.[5] But no cuneiform tablet yet deciphered presents a parallel; the hypothesis cannot be accepted in the total absence of corroborative evidence.

However, the nakṣatras are useful in the tracing of Indian influence on other cultures. The oldest lists [6] associate each constellation with a presiding deity who is to be suitably propitiated at the appointed times. It became important to perform certain sacrifices only under the benign influence of particularly auspicious nakṣatras.[7] The roster of activities for which each was considered auspicious or not was rapidly expanded,[8] and, in particular, the nakṣatras came to be closely connected with the twelve or sixteen saṃskâras or purificatory rites. Thereby they gave rise to the most substantial part of muhûrtaśâstra, or Indian catarchic astrology,[9] traces of which are to be found in Arabic, Byzantine, and medieval Latin texts.[10] The Indians also combined the twenty-eight nakṣatras with the Babylonian arts of brontology and seismology [11] in a form which, for some unknown reason,

[5] See the most recent, J. Needham, *Science and Civilization in China*, vol. 3, Cambridge, 1959, pp. 252-259. S. Weinstock, " Lunar Mansions and Early Calendars," *J. Hellenic Studies*, 1949, *69*: 48-69 is based on a series of misinterpretations.

[6] See, e.g., Taittirîyasaṃhitâ 4, 4, 10.

[7] P. V. Kane, *History of Dharmaśâstra*, vol. 5, pt. 1, Poona, 1958, pp. 506-507.

[8] *Ibid*., pp. 523-525.

[9] On muhûrtaśâstra, the oldest works seem to be: one of at least four versions of the Gargasaṃhitâ, that preserved in MS 210 of 1883/1884 of the Bhandarkar Oriental Research Institute, Poona, and MS 9277 of the Oriental Institute, Baroda; the Ratnakośa of Lalla (seventh century) in MS 27 of 1880/1881 of the Bhandarkar Oriental Research Institute and MS 1203 of the Viśveśvarânanda Vedic Research Institute, Hoshiarpur; and the Ratnamâlâ of Śrîpati (eleventh century), ed. by K. M. Chattopâdhyâya, Calcutta, 1915. See also P. Poucha, " La Jyotiṣaratnamâlâ ou guirlande des joyaux d'astrologie de Śrîpatibhaṭṭa," *Arch. Orientálni*, 1946, *16*: 277-309, and M. G. Panse, *Jyotiṣaratnamâlâ of Śrîpatibhaṭṭa, Bull. of the Deccan College Res. Inst.*, 1956, *17*: 237-502, reprinted in the Deccan College Monograph Series, Poona, 1957. Besides these three works, I know of more than 100 other Sanskrit texts, not including their commentaries, on the same subject.

[10] E. g., the text on the twenty-eight lunar stations comparing the theories of the Indians, the Persians (Sasanians using Indian sources), and Dorotheus (compiled from the fifth book of his Pentateuch, where the material is arranged under zodiacal signs, not lunar mansions, as is also the case in the poem of Maximus, which is largely derived from Dorotheus; of the Pentateuch there survives a late eighth-century Arabic translation of a third-century Pahlavi version in MS Yeni Jami 784 and MS Or. oct. 2663 of Berlin, now in Marburg). The Arabic original of this text is to be found in MS Add. 23,400 of the British Museum; the Greek version has been published by S. Weinstock in *Catalogus Codicum Astrologorum Graecorum*, ed. F. Cumont *et al.*, 12 vols. in 20 parts, Bruxelles, 1898-1953, vol. 9, pt. 1, pp. 138-156; the first five books of the Old Catalan version of 'Alî ibn abî 'r-Rijâl, who includes this text in his treatise, have been edited by G. Hilty, *El libro conplido en los iudizios de las estrellas*, Madrid, 1954; for editions and manuscripts of the Latin, which is a translation of the Old Catalan, see F. Carmody, *Arabic Astronomical and Astrological Sciences in Latin Translation*, Berkeley–Los Angeles, 1956, pp. 150-152. Cf. also John of Seville's Epitome astrologiae 4, 18 cited by J. M. Millás Vallicrosa, *Las traducciones orientales en los manuscritos de la Biblioteca Catedral de Toledo*, Madrid, 1942, pp. 157-158, and Carmody, *op. cit.*, p. 70.

[11] For the Babylonian origin of these two methods of divination, see C. Bezold and F. Boll, *Reflexe astrologischer Keilinschriften bei griechischen Schriftstellern*, Sitz. Heidelberger Akad. Wiss. Phil-hist. Kl. 1911, Abh. 7, Heidelberg, 1911, pp. 45-52, and P. Hilaire de Wynghene, *Les présages astrologiques*, Übersicht über die Keilschrift-literatur, Heft 3, Roma, 1932, p. 56.

became immensely popular among the followers of Buddha.[12] Their works spread these superstitions throughout Central Asia and the Far East.[13]

The relative seclusion from the West which the Aryans had enjoyed in northern India for centuries after their invasions was broken shortly before 513 B. C., when Darius the Great conquered the Indus Valley. In the ensuing six centuries, save for a century and a half of security under the Mauryan emperors, North India was subjected to the successive incursions of the Greeks, the Śakas, the Pahlavas, and the Kuṣâṇas. An important aspect of this turbulent period was the opportunity it afforded of contact between the intellectuals of the West and India. This opportunity was not missed.

In the period from 500 to about 230 B. C. — under the Achemenid occupation and during the reigns of Candragupta Maurya, Bindusâra, and Aśoka — Indian astronomy was introduced for the first time to some reasonable Babylonian methods, and astrologers were led to show an interest in more significant phenomena than the nakṣatras.[14] A luni-solar calendar was propounded in the Jyotiṣavedâṅga of Lagadha,[15] who probably wrote in the fifth century B. C. This calendar is described also in the Arthaśâstra of Kauṭilya,[16] which seems to be a Mauryan document; in the Jaina Sûryaprajñapti,[17] which probably preserves a Mauryan system; in the oldest version of the Gargasaṃhitâ,[18] which may have been written in the first century A. D.; and in the earliest version of the Paitâmahasiddhânta,[19] which uses as epoch 80 A. D. The period relation employed in this calendar — sixty-two synodic months in 1830 days — is extremely crude and, so far as I know, not Babylonian; but the attempt is analogous to the more accurate eight-year cycle introduced into Greece by Cleostratus of Tenedos towards the end of the sixth century B. C.

An important feature of the Jyotiṣavedâṅga is its use of the tithi, or thirtieth of a synodic month, as a standard unit of time. Tithis, of course, play a similar role in the Babylonian linear astronomy of the Seleucid period.[20] It seems likely that the Indians borrowed the concept from Mesopotamia, though the exact origin of the tithi still remains obscure.

12 See, *inter alia*, the Śârdûlakarṇâvadâna of the Divyâvadâna, ed. S. Mukhopadhyaya, Santiniketan, 1954, reprinted in the Divyâvadâna, ed. P. L. Vaidya, Buddhist Sanskrit Texts 20, Darbhanga, 1959.

13 For the Chinese material, see M. Zemba, " On the Astronomy and Calendar of the Buddhist Books," *J. Indian and Buddhist Studies*, 1956, *4*: 18-27, kindly translated from the Japanese for me by Professor Shoren Ihara of Kyushu University, Fukuoka, Japan.

14 For the Achemenid influence on art in Mauryan India, see, for example, R. E. M. Wheeler in *Ancient India*, 1948, *4*: 92-101 and the appendix by Stuart Piggott, *ibid.*, pp. 101-103.

15 The Jyotiṣavedâṅga of the Yajurveda and of the Ṛgveda with the commentary of Somâkara on the former were published by S. Dvivedî, Benares, 1908; see also the edition and translation of the text belonging to the Ṛgveda by R. Shamasastry, Mysore, 1936.

16 Kauṭalîyârthaśâstra 2, 20, ed. N. S. Venkatanathacharya, Oriental Res. Inst. Sanskrit Series 103, Mysore, 1960.

17 Ed. J. F. Kohl, Bonner Orientalistische Studien 20, Stuttgart, 1937; 10, 22 *et passim.*

18 Quoted by Somâkara on Jyotiṣavedâṅga 10.

19 Summarized by Varâhamihira in chap. 12 of his Pañcasiddhântikâ, ed. G. Thibaut and S. Dvivedî, Benares, 1889; reprinted Lahore, 1930. See also M. P. Kharegat, *J. Bombay Branch of the Roy. Asiatic Soc.*, 1896, *19*: 109-141.

20 See Neugebauer, *ACT*, vol. 1, p. 40. Despite Kane, *op. cit.*, pp. 62 ff., it cannot be said that the tithi was conceived of as a thirtieth of a synodic month before Lagadha.

In their methods of measuring the time of day, the Indians of this early period also showed a knowledge of what the Babylonians had devised.[21] One method depends on the length of the shadow cast by a śañku or gnomon. This shadow, of course, varies during any half-day with the changing altitude of the sun; it also varies from day to day throughout a half-year as the sun travels along the ecliptic. In tabulating the increase and decrease of the noon-shadow throughout the year, the Indians employed a linear zigzag system which is clearly of Babylonian origin. But, more than this, they used 3:2 as the ratio of the longest to the shortest day of the year, a well-known Babylonian parameter [22] which is not applicable to any part of India except the extreme Northwest.[23] The other Indian method of telling time, by means of a ghaṭa, or pot with a small hole in the bottom through which water flows at a fixed rate, is also known to have been employed in Babylon.[24] In connection with the śañku it may be added that if one can believe their claims as recorded by Eratosthenes and Hipparchus via Strabo,[25] both Megasthenes and Daimachus, the Seleucid ambassadors at the Mauryan capital, Pâtaliputra or Palibothra, made gnomon-observations in India.

Babylonian influence in astrology was equally great; in fact, the planets first appear in Indian literature because of it. Venus is mentioned as the " Star of Plants " (Osadhitârakâ) in an early Buddhist text, the Majjhimanikâya; [26] and Kauṭilya asserts that the sun, and Jupiter and Venus in their risings, settings, and stations, cooperate in furthering the growth of plants.[27] The heliacal risings and settings of the planets and their stationary points are the so-called Greek-letter phenomena upon which the structure of Babylonian linear planetary theory is based.

In the Indian epics, the Râmâyaṇa and the Mahâbhârata, the planets also appear in an astrological context, their influence depending on their conjunctions with the constellations, on their retrogressions, and on their transits.[28] This type of astrology is termed gocâra; it is mentioned in a

21 For the early Indian techniques of telling time, see H. Jacobi, " Einteilung des Tages und Zeitmessung im alten Indien," *Zeitschr. der Deutschen Morgenländischen Gesellschaft*, 1920, *74*: 247-263.

22 See O. Neugebauer, *Osiris*, 1936, *2*: 517, and *Exact Sciences*, p. 183.

23 B. R. Kulkarni, " Some Astronomical References from the Arthashastra and their Significance," *J. Univ. Bombay* (History, Economics and Sociology 33), 1948, *17,1*: 1-3, tries to use this fact to prove that Kauṭilya wrote in Kashmir. But he is wrong; Kauṭilya is simply copying blindly. In fact, other evidence in the Arthaśâstra indicates that it was written in Bihar; see G. D. Tamaskar, " The Country of Kauṭilya's Arthaśâstra," *Siddha-Bhâratî or The Rosary of Indology*, vol. 2, Hoshiarpur, 1950, pp. 226-229.

24 O. Neugebauer, " Studies in Ancient Astronomy, VIII. The Water Clock in Babylonian Astronomy," *Isis*, 1947, *37*: 37-43.

25 Strabo 2 C 76-77, ed. A. Meineke, Leipzig, 1903. This passage is not included in D. R. Dicks, *The Geographical Fragments of Hipparchus*, London, 1960, p. 68. Though the observations were not of a very high order of accuracy, still some interest was shown in the subject by the Greeks in India; cf. Diodorus Siculus 2, 35, ed. F. Vogel, Leipzig, 1888; Baeton cited in Pliny, Naturalis Historia 6, 69 and 2, 184 (with Onesicritus), ed. C. Mayhoff, Leipzig, 1906, with which compare Martianus Capella 6, 694, ed. A. Dick, Leipzig, 1925, Pomponius Mela 3, 61, ed. C. Frick, Leipzig, 1880, and Solinus 52, 13, ed. T. Mommsen, 2nd ed., 1895, reprinted Berlin, 1958.

26 Majjhimanikâya 2, 3, 7, ed. R. Chalmers, *Pali Text Society*, vol. 2, London, 1898, pp. 14, 34; cf. Buddhaghoṣa's Papañcasûdanî, ed. I. B. Horner, *Pali Text Society*, pt. 3, London, 1933, p. 274.

27 Arthaśâstra 2, 24.

28 Kane, *op. cit.*, pp. 531-532.

Buddhist anti-caste tract, the Śârdûlakarṇâvadâna,[29] which was probably written in the first century A. D. and is described in detail in the Gargasaṃhitâ [30] and in the sixth-century Bṛhatsaṃhitâ of Varâhamihira.[31] It represents an earlier stage of planetary astrology than does Hellenistic horoscopy; in fact, it is a method familiar from the reports of the astrologers of Babylon and Ninevah.[32] From a Babylonian source also comes the order in which the celestial bodies are named in the early second-century Nasik cave-inscription set up by his mother in honor of Gautamîputra Śâtakarṇi [33] and in a common Paurâṇika passage; [34] according to these sources the sun and moon precede the five star-planets.[35] There is no hint, however, that the Indians had learned a method of computing planetary positions in this period.

I have mentioned previously the Śaka or Scythian invasions of North India; it is necessary now to return to them. A family of Śakas, the Kṣaharâtas, established a kingdom in western India at the beginning of the first century A. D.[36] Their capital was Mînanagara,[37] but their source of wealth, Bhṛgukaccha, the modern Broach, was one of the main emporia for the brisk trade between India and the Mediterranean; it was known to the Greeks by the name Barygaza.[38] The Periplus maris Erythraei, a document written between 60 and 80 A. D., mentions the Kṣaharâta king Nahapâna,[39] whose riches are extolled in Jaina traditions and proved by the vast hoard

29 P. 31 Mukhopadhyaya.

30 Quoted by Bhaṭṭotpala on Bṛhatsaṃhitâ 4 and 6-10, ed. S. Dvivedî, Vizianagram Sanskrit Series 10, 2 vols., Benares, 1895-1897. This subject is also treated in the version of the Gargasaṃhitâ cited above in fn. 9 and in another found in MS 542 of 1895/1902 of the Bhandarkar Oriental Research Institute, MS G 8199 of the Asiatic Society of Bengal, Calcutta, MS 122 of the Jyotiṣa collection of the Sanskrit College, Benares, and MS fonds sanscrit 245 (1) of the Bibliothèque Nationale, Paris.

31 Chaps. 4 and 6-10.

32 See R. C. Thompson, *The Reports of the Magicians and Astrologers of Ninevah and Babylon in the British Museum*, London, 1900, *passim*.

33 Ed. E. Senart, *Epigraphia Indica*, 1905-1906, *8*: 60-65 (hereafter *EI*).

34 See J. F. Fleet, "A Note on the Purâṇas," *J. Roy. Asiatic Soc.*, 1912, 1046-1053 (hereafter *JRAS*), and "The Purâṇic Order of the Planets," *JRAS*, 1913, 384-385; and W. Kirfel, *Das Purâṇa vom Weltgebäude*, Bonner Orientalistische Studien, NS 1, Bonn, 1954, p. 278.

35 For the Babylonian order, see F. Boll in *Realencyclopädie der classischen Altertumswissenschaft*, 1912, *14*: cc. 2561-2570.

36 On the Śakas, see especially S. Chattopadhyaya. *The Śakas in India*, Viśva-Bharati Studies in Santiniketan, 1955, and J. N. Banerjea in *A Comprehensive History of India*, vol. 2, ed. K. A. Nilakanta Sastri, Bombay-Calcutta-Madras, 1957, chap. 9.

37 Periplus maris Erythraei 41 (Μινναγάρα), ed. H. Frisk, *Göteborgs Högskolas Årsskrift* 33, Göteborg, 1927, and Ptolemy, Geography 7, 1, 63 (Μινάγαρα), ed. L. Renou, *La Géographie de Ptolémée: L'Inde (VII, 1-4)*, Paris, 1925. There are also two other Scythian cities called "City of the Mînas"; one, in Seistan, is mentioned by Isidore of Charax 18 (Μὶν πόλις), ed. W. H. Schoff, Philadelphia, 1914, and the other, near the mouth of the Indus, in Periplus 38 (Μινναγάρ) and in Ptolemy 7, 1, 61 (Βιναγάρα).

38 On this trade, see now M. P. Charlesworth, "Roman Trade with India: A Resurvey," *Studies in Roman Economic and Social History in Honor of Allan Chester Johnson*, Princeton, 1951, pp. 131-143, and U. N. Ghoshal in *A Comprehensive History of India*, vol. 2, pp. 439-446.

39 The date of the Periplus and the reference to Nahapâna have recently been questioned by J. Pirenne, *Le royaume sud-arabe de Qatabân et sa datation*, Bibliothèque du Muséon, 48, Louvain, 1961, chap. 5. Her arguments are not entirely convincing; but even were they to prove correct, the conclusions reached in this paper would not be affected. Whether the Periplus refers to Nahapâna or not, I would not connect him with the Śaka era of 78 A. D.

of 14,000 silver coins found at Jogalthembi. This wealth depended largely on the Roman trade. The Śakas exported, besides many other articles, Chinese silk carried across Central Asia, through Kuṣâṇa territory down the Indus, across to Ujjain, and down the Narmadâ valley to Broach. In return they received, along with other useful products of Roman industry, dancing-girls and jugs of wine. In innumerable sites in Gujarât, Saurâṣṭra, and northern Mahârâṣṭra there have been unearthed fragments of Roman pottery and its imitations, copies of Roman bullae, Roman beads, and Roman statuettes, all of which date from the first to fourth centuries A. D.[40] A large number of inscriptions of the first and second centuries found in the Buddhist caves along the trade-routes of the western Ghâṭs record the donations of the Yavanas, or Greeks of Dhenukâkaṭa.[41] Indeed, one can date the Greek settlement in the area back to Mauryan times if one is willing to accept as sufficient evidence the Junâgaḍh inscription which mentions the Yavanarâja Tuṣâspa, who was Aśoka's governor of Kâṭhiâwâḍ.[42] It does not seem likely, however, despite Tarn's strenuous efforts,[43] that the Greek kingdom of Demetrius and Menander ever extended this far south, though Greeks from Gandhâra may well have made commercial trips to Bhṛgukaccha and Ujjain and augmented the Yavana community in Gujarât. Ptolemy's source was perhaps taking note of the Greek settlements when he placed towns with such un-Indian names as Byzantion on the coast below Barygaza.[44]

By Ptolemy's time, however, the Kṣaharâta dynasty had been overthrown by the Sâtavâhana Gautamîputra Śâtakarṇi,[45] whom we have had occasion to mention before, and he in turn had succumbed to a new Śaka dynasty, the western Kṣatrapas, in Gujarât and Saurâṣṭra. The greatest of the Kṣatrapas was Rudradâman I, who ruled from about 130 to about 160 A. D. His empire at one time extended over most of Central India, stretching as far as Kauśâmbî in the North and Kaliñga in the East.[46] His capital was Ujjain, which for this reason became the Greenwich of Indian astronomers and the Arin of the Arabic and Latin astronomical treatises; for it was he and his successors who encouraged the introduction of Greek horoscopy and astronomy into India.

In 150 A. D. Yavaneśvara, the Lord of the Greeks, translated into Sanskrit prose a Greek astrological text which had been written in Alexandria in the preceding half-century. This translation is now lost, but there is pre-

[40] See Appendix 1 for the beginning of a bibliography of this material (sites in South India such as Arikamedu and Chandravalli are excluded).

[41] See D. D. Kosambi, "Dhenukâkaṭa," *J. Asiatic Soc. of Bombay*, 1955, *30*, pt. 2: 50-71.

[42] Ed. F. Kielhorn, *EI*, 1905-1906, *8*: 39-49.

[43] W. W. Tarn, *The Greeks in Bactria and India*, 2nd ed., Cambridge, 1951, pp. 147-150, 230; contrast the more sensible account in A. K. Narain, *The Indo-Greeks*, Oxford, 1957, pp. 91-95.

[44] Ptolemy 7, 1, 7.

[45] See fn. 33. The inscription associates the Greeks and the Pahlavas in Nahapâna's defeat.

[46] D. Pingree, "The Empires of Rudradaman and Yaśodharman: Evidence from Two Astrological Geographies," *J. Amer. Oriental Soc.*, 1959, *79*: 267-270 (hereafter *JAOS*). An inscription of one Rudradâmaśrî, dated paleographically to the third or fourth century, has recently been found in Mirzapur District, UP; see *Indian Archaeology 1959-60 — A Review*, New Delhi, 1960, p. 61; now published by D. C. Sircar in *EI*, 1961-1962, *34*: 244-245.

served in an early thirteenth-century palm-leaf manuscript in Kathmandu [47] a versification of it made in 270 by the Yavanarâja Sphujidhvaja. In the second century another Greek text on the same subject was translated into Sanskrit; this text and Yavaneśvara's were both used by a third-century author named Satya. Unfortunately, the second translation from the Greek is lost, and Satya's work is known only from the citations of later astrologers and in what appears to be a fairly recent forgery. However, there has survived a work based on both Sphujidhvaja and Satya; this is the Vṛddhayavanajâtaka of Mînarâja.[48]

The name Mînarâja connects its owner with the Mînas whom we have already come across in Mînanagara, the Kṣaharâta capital. Two other Mînanagaras are known, and they also are Scythian cities. Mînarâja, then, must have been a Śaka. But he also calls himself the Yavanarâja, or King of the Greeks, a title used by Tuṣâspa, Yavaneśvara, and Sphujidhvaja. One can now also cite an early fourth-century inscription discovered at Nâgârjunakoṇḍa [49] which mentions the Śaka of Ujjain, Rudradâman II (*c.* 335–*c.* 345), and the Yavanarâja of Sañjayapuri (Sañjayapuri is probably the same as Sañjayantî, the modern Sañjân near Bombay, which Ptolemy, who included it within the kingdom of the western Kṣatrapas, calls Sazantion).[50] Yavanarâja, then, was an official title in the Śaka administration. As the Śakas were overthrown by Candragupta II shortly after 389,[51] and as the Vṛddhayavanajâtaka copies many ślokas from Sphujidhvaja, it is safe to date Mînarâja in the early fourth century; and we have recovered two astrological poems presenting almost purely Greek horoscopy in Sanskrit.

Indian genethlialogy is largely dependent on the teachings of Yavaneśvara and Satya, though elaborations have been indulged in from time to time; and it, in turn, has influenced Sasanian, Arabic, Byzantine, and western European astrology. But it is more important for our present purpose to examine the planetary theory given at the end of Sphujidhvaja's Yavanajâtaka than the spread of the science of astrology. The system and the parameters in this planetary theory are precisely identical with those found on cuneiform tablets of the Seleucid period. It is clear, then, that Babylonian linear astronomy was transmitted to India by the Greeks.[52] Normally, of course, Greek astronomical texts are devoid of these methods; but van der Waerden

[47] Durbar Library 1180A.

[48] On the interrelationships of these texts, see my unpublished thesis, *Materials for the Study of the Transmission of Greek Astrology to India*, submitted at Harvard in 1960, and forthcoming editions of Sphujidhvaja and Mînarâja.

[49] *Indian Archaeology 1958-59 — A Review*, New Delhi, 1959, p. 8; *Indian Archaeology 1959-60 — A Review*, New Delhi, 1960, p. 54. The inscription cannot be dated in the year 30 of the Kalacuri Era (278/279 A.D.) as suggested by D. C. Sircar in *Indian Historical Quart.*, 1960, *36*: 24 f. (hereafter *IHQ*). This inscription has now been published by D. C. Sircar and K. G. Krishnan in *EI*, 1961-1962, *34*: 20-22.

[50] See H. Raychaudhuri in *The Early History of the Deccan*, ed. G. Yazdani, vol. 1, London-Bombay-New York, 1960, p. 55; Mahâbhârata, Sabhâparvan 28, 47, ed. F. Edgerton, Poona, 1944 (Antioch, Rome, and the City of the Greeks — Alexandria — are mentioned in 28, 49); and Ptolemy 7, 1, 63.

[51] P. L. Gupta, "Who Ruled in Saurâṣṭra after the Western Kshatrapas?" *Bhâratîya Vidyâ*, 1958, *18*: 83-89.

[52] D. Pingree, "A Greek Linear Planetary Text in India," *JAOS*, 1959, *79*: 282-284.

and Neugebauer have shown that the Babylonian linear system lies behind the so-called Egyptian Eternal Tables [53] and appears in an astrological text ascribed to the late fifth-century author Heliodorus [54] (van der Waerden's claim to have found more than a few Babylonian parameters in the Thesauri of the sixth-century astrologer Rhetorius of Egypt [55] cannot be accepted). We may conclude, therefore, that at least some Greek astrologers ignored the epicyclic and eccentric theories developed by Apollonius, Hipparchus, and Ptolemy, and adhered to the Babylonian methods; and the Greek who wrote the original of the Yavanajâtaka in Alexandria between 100 and 150 A. D. was one such astrologer.

Sphujidhvaja mentions the work of the sage Vasiṣṭha; and it is likely that from the Vasiṣṭhasiddhânta are derived the first fifty-six verses of the eighteenth book of Varâhamihira's Pañcasiddhântikâ, which contain another Sanskrit version of Babylonian linear planetary theory. The second book of the Pañcasiddhântikâ contains a summary of the solar and lunar theories of the Vasiṣṭhasamâsasiddhânta.[56] The lunar theory is based on two well-known Babylonian period relations, which also occur in Greek papyri of the second and third centuries A. D.[57] — the equivalence of nine anomalistic months to 248 days and that of 110 anomalistic months to 3031 days. These same two period relations are found in the Pauliśasiddhânta [58] and in the thirteenth-century Candravâkyas of Vararuci,[59] while the second appears in

[53] For the Eternal Tables themselves, see O. Neugebauer, *Egyptian Planetary Texts*, *Trans. Amer. Phil. Soc.*, 1942, *NS 32*, pt. 2; for their use of Babylonian parameters, see B. L. van der Waerden, "Egyptian 'Eternal Tables,'" *Proc. Sect. Sciences, Kon. Ned. Akad. Wet.*, 1947, *50*: 536-547, 782-788; "Babylonische Planetenrechnung in Ägypten und Indien," *Bibl. Or.*, 1956, *13*: 108-110; *Centaurus*, 1958, *5*: 177; and "Babylonische Methoden in ägyptischen Planetentafeln," *Vjschr. Naturf. Ges. Zürich*, 1960, *105*: 97-144. See also a Demotic text edited by R. A. Parker, "Two Demotic Astronomical Papyri in the Carlsberg Collection," *Acta Orientalia*, 1962, *26*: 143-147 (P. Carlsberg 32 uses Babylonian methods); a Greek papyrus of a similar nature is to be published in *Papiri Greci e Latini* 15.

[54] O. Neugebauer, "On a Fragment of Heliodorus (?) on Planetary Motion," *Sudhoffs Archiv*, 1958, *42*: 237-244. E. Boer, in her edition of Paulus Alexandrinus, Leipzig, 1958, p. 28, says that this passage is not by Heliodorus, and she does not include it in her edition of Heliodorus (?), Leipzig, 1962, pp. 11-12.

[55] *Vjschr. Naturf. Ges. Zürich*, 1955, *100*: 165; Rhetorius' period (1,753,005 years) and planetary parameters are different from the Indian parallels adduced by van der Waerden, and there is no evidence to support the hypothesis that a yuga-system of astronomy was ever known in Greece, much less in Babylon. Professor Neugebauer, who has examined a photograph of the manuscript, informs me that one should read 1,753,200 rather than 1,753,005 (i. e., a c for an ϵ).

[56] For a complete explanation of these obscure verses, see T. S. Kuppanna Sastri, "The Vâsiṣṭha Sun and Moon in Varâhamihira's Pañcasiddhântikâ," *J. Orient. Res., Madras*, 1957, *25*: 19-41. This work is different from the Vasiṣṭhasiddhânta ed. by V. P. Śarmâ, Benares, 1907, and the Vṛddhavasiṣṭhasiddhânta ed. by V. P. Dvivedi in his *Jyautiṣasiddhânta-sañgraha*, Benares Sanskrit Series, fasc. 2, Benares, 1912, pt. 2.

[57] E. J. Knudtzon and O. Neugebauer, "Zwei astronomische Texte," *Bull. Soc. roy. lettres de Lund*, 1946-1947, pp. 77-78; O. Neugebauer, "The Astronomical Treatise P. Ryl. 27," *Det Kgl. Danske Vid. Selskab., hist.-fil. medd.*, 1949, *32*: 2, København; O. Neugebauer, *Exact Sciences*, pp. 161-167, 185-187; and B. L. van der Waerden, "The Astronomical Papyrus Ryland 27," *Centaurus*, 1958, *5*: 177-191.

[58] Pañcasiddhântikâ 3, 4.

[59] Ed. C. Kunhan Raja, Madras, 1948, and in the Haricarita of Parameśvara Bhaṭṭa, ed. V Krishnamacharya, Adyar Library Series 63, Madras, 1948. Neither of these publications was known to the scholars who recognized Babylonian parameters in the vâkya-system; O. Neugebauer, "Tamil Astronomy," *Osiris*, 1952,

the Romakasiddhânta [60] and in the Uttarakhaṇḍa of Brahmagupta's Khaṇḍakhâdyaka.[61] The Vasiṣṭhasamâsasiddhânta computes the true longitude of the moon according to a Babylonian linear zigzag system; and a linear system is the basis of Vasiṣṭha's solar theory, as it also is of Pauliśa's. Therefore, it is apparent that the earliest form of astronomy introduced into India by the Greeks was entirely Babylonian in origin.

Greek epicyclic theory soon followed, however, and probably under the patronage of the same Śaka dynasty of Ujjain. If the last verses of the last chapter of the Pañcasiddhântikâ are in fact based on the Pauliśasiddhânta, then Puliśa — who, despite Bîrûnî,[62] has nothing to do with the fourth-century astrologer Paulus of Alexandria [63] — gives the same values for the mean synodic arcs of the planets as appear in cuneiform tablets.[64] But Puliśa computed solar longitude according to the epicyclic theory,[65] and he included in his siddhânta all of the trigonometry necessary for the solution of problems in epicyclic astronomy, including a table of sines derived from the Greek table of chords.[66]

Later in the fourth century, probably not long after the Pauliśasiddhânta, was written the Romakasiddhânta,[67] whose name betrays its origin. That

10: 252-276; B. L. van der Waerden, "Die Bewegung der Sonne nach griechischen und indischen Tafeln," *Sitzungsber. Bayer. Akad. Wiss., math.-naturwiss. Kl.*, 1952, Nr. 18; I. V. M. Krishna Rav, "The Motion of the Moon in Tamil Astronomy," *Centaurus*, 1955-1956, *4*: 198-220; and B. L. van der Waerden, "Tamil Astronomy," *ibid.*, 221-234.

60 Pañcasiddhântikâ 8, 5.

61 Khaṇḍakhâdyaka 9, 5 in the edition with the commentary of Pṛthûdakasvâmin by P. C. Sengupta, Calcutta, 1941, and in his English translation, Calcutta, 1934; this chapter is not included in the edition with the commentary of Âmarâja by Babua Miśra, Calcutta, 1925.

62 *Alberuni's India*, trans. E. C. Sachau, vol. 1, London, 1914, p. 153.

63 There are at least three Pauliśa- (or Puliśa) siddhântas. The first is the original work, probably of the fourth century; it is lost. The second is the edition of Lâṭadeva, written around 505 A.D.; it also is lost, but a summary is preserved in the Pañcasiddhântikâ. The third is a later work modeled on a standard Indian siddhânta; it is lost except for quotations and references in the commentaries of Pṛthûdaka and Bhaṭṭotpala and in Bîrûnî's works. As Bîrûnî knows only this third Puliśa, his statement probably has no relevance for the first and makes no sense if applied to the text he had before him. Moreover, in the one detail in which the second Puliśa (Pañcasiddhântikâ 3, 17) and Paulus Alexandrinus (28) overlap — the values of the mean daily motion of the sun for the different months in a year — they do not agree. However, the name Pauliśa might still be a Sanskrit version of Paulus; the Pauliśasiddhânta did feel it necessary to give corrections for the differences in longitude between Yavanapura (Alexandria) and Avanti (Ujjain) and Vârâṇasî (Benares); see Pañcasiddhântikâ 3, 13.

64 Neugebauer, *Exact Sciences*, pp. 172-173, 189.

65 Pañcasiddhântikâ 3, 1-3.

66 *Ibid.* 4, 1-15.

67 There are apparently five Sanskrit works of this title. The history of the first two is the same as that of the first two versions of the Pauliśasiddhânta. The third is a revision by Śrîṣeṇa mentioned by Brahmagupta in Brâhmasphuṭasiddhânta 11, 50-51, and elsewhere. The fourth, which is also called Śrîṣavâyaṇa, is preserved in at least twenty-two manuscripts: MSS 34 of 1870/1871, 106 of 1873/1874 and 411 of 1884/1886 of the Bhandarkar Oriental Research Institute, Poona; MSS 3279, 9329, 9376, 13333, and 13421 (i) of the Oriental Institute, Baroda; MS 2790 of the Raghunatha Temple Library of the Mahârâja of Jammu and Kashmir; MSS 4643, 4777, 5068, and 5069 of the Anup Sanskrit Library, Bikaner; MS Or. fol. 981b of Berlin, now at Tübingen; MS 1805 of the India Office Library, London; MS Add. 14,365o of the British Museum, London; MS Wilson 157d of the Bodleian Library, Oxford; MS 8 of the Sanskrit College Library, Benares; MSS 378, 379, and 460 of the Library of the University of Bombay; and MS 259 of the Library of the Asiatic Society of Bombay. This text is obviously based on an Arabic work; see T. Aufrecht, *Catalogi Codicum Manuscriptorum Bibliothecae Bodleianae pars octava, Codices Sanscriticos com-*

origin is also revealed by the fact that the Romaka gives a luni-solar cycle of 2850 years,[68] which is equivalent to the Metonic cycle of 19 years multiplied by 150 so that its tropical year may be equal to Hipparchus', or 365 days plus 1/4 minus 1/300. And whereas Puliśa seems to have used an epicyclic model only for the sun, the Romaka applies this method to both luminaries.[69] Nothing is known of its planetary theory.

Both of these texts were probably based on translations from the Greek made under the patronage of the Kṣatrapas of Ujjain. That dynasty, however, became greatly weakened towards the end of the fourth century, and a new nationalistic state, the Gupta Empire, gained the hegemony of North India. It is an attractive hypothesis to suppose that the court of Samudragupta or of Candragupta II [70] encouraged an important development in Indian astronomy, the merging of two concepts of foreign origin into a new theory of planetary motion. To understand what was achieved we must briefly consider the kalpa.

A kalpa is a period of 4,320,000,000 years; 72,000 of these kalpas or 311,040,000,000,000 years constitute the life of Brahma. Each kalpa is divided into 1000 equal parts called mahâyugas, which are 4,320,000 years apiece, and each mahâyuga contains four smaller yugas which are in the ratios to each other of 4:3, 3:2, and 2:1. The last yuga, then, the kaliyuga, is 1/10 mahâyuga, or 432,000 years. This is a Babylonian number: sexagesimally it would be written 2,0,0,0. It is the span of time given to the Babylonian kingdom before the Flood in the histories of Berossos [71] and Abydenus.[72] It seems likely that it should have become known as a significant number in India at the time when other Babylonian influences were being felt, that is, during the Achemenid occupation of the Indus Valley. In fact, the kalpa appears with an eschatological connotation in the fourth and fifth Rock Edicts of Aśoka [73] and in the Dîghanikâya.[74] However, the first text to describe the kalpa precisely as I have just done was a pre-second-century work which was the common source [75] of a passage occurring in the twelfth book of the Mahâbhârata [76] and in the first book of the Manusmṛti.[77]

plectens, Oxford, 1864, pp. 338-340. The fifth Romaka- (Romaśa) siddhânta is contained in MS 377 of the Library of the University of Bombay. Versions two, three, and perhaps five are dealt with, though not thoroughly, in S. B. Dikshit, "The Romaka Siddhantas," *Indian Antiquary*, 1890, *19*: 133-142; for two, see also J. Burgess, *ibid.*, 284-285.

68 Pañcasiddhântikâ 1, 15; see Thibaut, *op. cit.*, intr. xxvii-xxviii.

69 Pañcasiddhântikâ 8, 1-6.

70 Though the details cannot be accepted, there is little reason to doubt the genuineness of the tradition that Candragupta II was a great patron of learning, including astronomy and astrology, preserved in pseudo-Kâlidâsa's Jyotirvidâbharaṇa 22, 8-12, ed. Sîtarâma Śarmâ, Bombay, 1908.

71 P. Schnabel, *Berossos und die babylonisch-hellenistische Literatur*, Leipzig-Berlin, 1923, fr. 29-30a, pp. 261-263.

72 Fr. 1 in C. Muller, *Fragmenta Historicorum Graecorum*, vol. 4, Paris, 1851, p. 280.

73 E. Hultzsch, *Inscriptions of Asoka, CII* 1, new ed., Oxford, 1925, pp. 189, 191.

74 Dîghanikâya 25, 18 and 28, 16, ed. J. E. Carpenter, *Pali Text Society*, vol. 3, London, 1911, pp. 51, 111; Añguttaranikâya, Catukkanipâta, 156, ed. R. Morris, *Pali Text Society*, pt. 2, London, 1888, p. 142.

75 See G. Bühler, *The Laws of Manu, Sacred Books of the East*, vol. 25, Oxford, 1886, pp. lxxxii-xc (hereafter *SBE*).

76 Mahâbhârata, Śântiparvan 224, 12-30, ed. S. K. Belvalkar, Poona, 1951.

77 Manusmṛti 1, 64-74, ed. with the commentary of Kullûka by Nârâyaṇ Râm Âchârya, 10th ed., Bombay, 1946.

This kalpa of ultimately Babylonian origin was combined by Indian astronomers of the late fourth or early fifth centuries with Greek epicyclic theory. The mean motions of the planets can be described in terms of an integer number of revolutions within a given period as long as that period is fairly long; obviously the kalpa and the mahâyuga were ideally suited for such a use. But a shorter period, 1/24 mahâyuga, or 180,000 years, was employed also. This was the yuga which seems to have been the basis of the system of the original Old Sûryasiddhânta,[78] a work known to us now only through Varâhamihira's summary of the recension made by Lâṭadeva in 505 A. D.[79] The beginning of the yuga was taken to be a mean conjunction of all the planets at Aries 0° at midnight between 17 and 18 February –3101.

The period of 180,000 years, however, was not long enough to permit the use of very accurate parameters. The mahâyuga was somewhat better, though not as good as might be expected. For the mean conjunction in –3101 was taken to mark the beginning of the last and smallest yuga, the kaliyuga of only 432,000 years. Since the mahâyuga itself had to begin with a similar conjunction, one was forced to fit the parameters into a period only 1/10 as long as the whole yuga in order that the conjunction of the beginning of the kaliyuga might in fact take place. Practically speaking, then, one had a period only 2 2/5 as long as 180,000 years rather than one 24 times as long. Âryabhaṭa in 499 solved this problem in part by making the four yugas within the mahâyuga equal; [80] this gave him an effective period of 1,080,000 years. But this defiance of tradition was not welcomed by many in India.

However, even before Âryabhaṭa astronomers had realized the advantages of working with a kalpa,[81] despite the enormous numbers with which one had to compute. That the parameters could be further refined was perhaps not as decisive a factor in their choice of the longer period as the fact that its length allowed one to begin the system with a true conjunction rather than with the mean conjunction which the original Old Sûryasiddhânta and Âryabhaṭa had to accept. For the kalpa gave one enough time to pull the apogees back to the beginning of the zodiac and to endow them with such a slow motion that they would have reached their proper positions in the fifth century A. D.

The Indians of the Gupta Age, therefore, seem to have been the originators of the yuga-system of astronomy and to have developed variants em-

[78] Pañcasiddhântikâ 1, 14.

[79] I have recently found fragments of Lâṭadeva's work in Pṛthûdaka's commentary on Brahmagupta's Brâhmasphuṭasiddhânta preserved in MS 1781 of the Viśveśvarânanda Vedic Research Institute, Hoshiarpur; MS 339 of 1879/1880 of the Bhandarkar Oriental Research Institute, Poona; and MS 1304 of the India Office Library, London. These should make Lâṭa's role in the development of jyotiḥśâstra much clearer than it is at present.

[80] Âryabhaṭîya, Daśagîtikâ 3, ed. with the commentary of Parameśvara by H. Kern, Leyden, 1874; cf. Brâhmasphuṭasiddhânta 1, 9.

[81] The siddhânta of Svayambhû (Brahman) to which Âryabhaṭa refers in Golâdhyâya 50 most probably was based on the kalpa-system; see the Paitâmaha- (Brahma) siddhânta, ed. by V. P. Dvivedi in *Jyautiṣasiddhântasañgraha*, fasc. 2, pt. 1, and the Brâhmasphuṭasiddhânta (corrected Brahmasiddhânta) of Brahmagupta.

ploying periods of 180,000, 4,320,000, and 4,320,000,000 years. The elements which they used were admittedly of Greek and Babylonian derivation, but only they had the necessary theoretical knowledge and the inspiration.

Our subsequent remarks will indicate the absence of any evidence for much knowledge or inspiration in Sasanian astronomy. But first it is necessary to mention an intriguing community in India which was, I believe, the only post-Achemenid group of Iranians who were in a position historically to influence the development of Indian astronomy and astrology before the Muslim invasions. The Pahlavas, who had established kingdoms in northwestern India in the first century B. C., left descendants who became integrated into Hindu society as a special class of Brâhmaṇas, the Maga Brâhmaṇas; [82] the great sixth-century astrologer Varâhamihira was one of their number.[83] They are known from various reports, all of which portray them as good Hindus whose only idiosyncrasy was an inordinate devotion to the sun. But the important fact about these Magi is that they seem to have had no contact with Iran after the first century A. D., and no one would suggest that the Pahlavas knew of yuga astronomy.[84]

In fact, virtually nothing is known of the astronomy and astrology of pre-Sasanian Iran. There was indeed a Greek astrological text of the second century B. C. ascribed to Zoroaster of which fragments are preserved by Proclus and the Geoponica; [85] the material with which it deals is overwhelmingly Babylonian.[86] But there is reason to believe that it is the product of the Magusaeans of Asia Minor and in no way reflects scientific knowledge in Iran. However, we have seen before that certain Babylonian astronomical and astrological theories were transmitted to India during the Achemenid occupation of the Indus Valley; it is difficult to believe that the Persians were not exposed to the same influences as their remote vassals in India. In fact, a linear shadow text which may be an echo of this influence is preserved in the ninth-century Pahlavi Shâyast Lâ-shâyast.[87]

We have previously mentioned the fact that Buddhists introduced nakṣatra astrology into Iran and Central Asia. The Śârdûlakarṇâvadâna, which contains a thorough exposition of this system, was extremely popular in this area. It was summarized in Chinese by the Parthian prince An Shih-kao

[82] On the Maga Brâhmaṇas, see the most recent, R. C. Hazra, *Studies in the Upapurâṇas*, vol. 1, Calcutta Sanskrit College Res. Series 11, Calcutta, 1958, pp. 29-108.

[83] D. K. Biswas, "The Maga Ancestry of Varâhamihira," *IHQ*, 1949, *25*: 175-183.

[84] The Sasanians, of course, occupied at least some parts of the Indus Valley where the Kuṣâṇas once had reigned, but the extent of their rule was quite limited; see E. Honigmann and A. Maricq, *Recherches sur les Res Gestae Divi Saporis*, Mem. Acad. Roy. de Belgique, Cl. des Lettres 47, 4, Bruxelles, 1953, pp. 94-100, 107 fn. 6. Their cultural influence seems to have been nil. Save for his acceptance of Herzfeld's interpretation of the Paikuli inscription, now disproved by Maricq, the account in A. S. Altekar, "The Extent of the Sassanian Political Domination in India," *M. P. Khareghat Memorial Volume*, vol. 1, Bombay, 1953, pp. 213-220 is a sober summary of what little information is available on this subject.

[85] The fragments (074-097) are collected in J. Bidez and F. Cumont, *Les Mages hellénisés*, vol. 2, Paris, 1938, pp. 207-242; see also fr. 012-052, pp. 158-197.

[86] Pingree, *Materials*, pp. 39, 43, 51-52, 55-62.

[87] Chap. 21, trans. E. W. West, *SBE*, vol. 5, Oxford, 1880, pp. 397-400.

in the second century A. D.[88] and fully translated twice in the third.[89] A long fragment of the Sanskrit text written in about 500 A. D. was among the Weber manuscripts found south of Yarkand,[90] and fragments of fifth-century manuscripts of the Mahâmâyûrîvidyârâjñî, which also deals with nakṣatra astrology to some extent, are preserved among the Bower and Petrovski manuscripts from Kashgar.[91] To reach these places the texts most probably passed through Buddhist communities in the eastern provinces of the Sasanian Empire; and one finds the remains of this Buddhist influence in the second chapter of the Bundahishn, where the twenty-eight nakṣatras are listed with Persian names.[92] Also connected with this type of astrology perhaps is the theory that the moon is the bestower of all benefits upon mankind, which is mentioned in the ninth-century Dâdistân-î Dînîk.[93] Perhaps, if Tabarî's story is not entirely fictitious, the " goodness of birth " which the astrologers observed for the first Ardashîr[94] was the presence of the moon in an auspicious nakṣatra. One might also suggest that Firdôsi's frequent references to the good or bad achrat or constellation of an individual[95] are to be interpreted in a similar way.

However, trustworthy knowledge of Iranian astronomy and astrology is non-existent before the reign of Shâpûr I (240-270). He encouraged the spread of Greek and Indian science within his realm.[96] The hexameters of the first-century astrologer Dorotheus of Sidon, preserved only in fragments in Greek, were translated into Pahlavi under Shâpûr; we now have a late eighth-century Arabic translation of this Pahlavi version made by 'Umar ibn Farrukhân.[97] From this it is clear that the original third-century Pahlavi version was revised at the end of the fourth or the beginning of the fifth century, and some Indian theories were added — in particular, that of the navâṃśas or ninths of a sign. This mixture of Greek and Indian material is characteristic of the Sasanians; it is found also in the fragments of an Arabic translation of the Pahlavi version of the Anthologies of the second-century astrologer Vettius Valens, fragments recently identified by Pro-

[88] Trans. pp. 213-217 Mukhopadhyaya; on An Shih-kao, see E. Zürcher, *The Buddhist Conquest of China*, vol. 1, Leiden, 1959, pp. 32-34.

[89] Pp. xii-xiii Mukhopadhyaya.

[90] Ed. A. F. R. Hoernle, *J. Asiatic Soc. of Bengal*, 1893, *62*: 9-17.

[91] For the Mahâmâyûrî, see S. Oldenburg, *Zapiski Vostočnago otdyeleniya Imp. Russk. Arkheol. Obstchestva* 11, 1897-1898, St. Petersburg, 1899, pp. 218-261; A. F. R. Hoernle, *The Bower Manuscript*, Arch. Surv. India, New Imperial Series 22, Calcutta, 1893-1912, pts. 6-7, pp. 222-240e and pl. xlix-liv; and S. Lévi, " Le catalogue géographique des Yakṣa dans la Mahâmâyûrî," *J. asiatique*, 11e série, 1915, *5*: 19-138.

[92] Bundahishn 2, 2, trans. E. W. West, *SBE*, vol. 5, Oxford, 1880, p. 11; see W. B. Henning, " An Astronomical Chapter of the Bundahishn," *JRAS*, 1942, 229-248.

[93] Dâdistân-î Dînîk 71, 2, trans. E. W. West, *SBE*, vol. 18, Oxford, 1882, p. 215.

[94] *Annales quos scripsit . . . at-Tabarî*, ed. M. J. de Goeje, prima series, vol. 2, ed. J. Barth and T. Nöldeke, Leiden, 1881-1882, p. 815.

[95] The references are collected by J. Scheftelowitz in *Zeitschr. für Indologie und Iranistik*, 1926, *4*: 326-328.

[96] See the Dênkart quoted by R. C. Zaehner in *Zurvan: A Zoroastrian Dilemma*, Oxford, 1955, p. 8.

[97] See *Kitâb al-Fihrist*, ed. G. Flügel, vol. 1, Leipzig, 1871, p. 239; C. A. Nallino in *A Volume of Oriental Studies Presented to Professor E. G. Browne*, Cambridge, 1922, pp. 262-263, reprinted in his *Raccolta di scritti editi e inediti*, vol. 6, Roma, 1948, pp. 302-303. See also fn. 10 above.

fessor Kennedy in a manuscript in the British Museum.[98] Bîrûnî says that this Pahlavi work is one of the main sources of Abû Ma'shar's Magnus Introductorius.[99] The same British Museum manuscript preserves parts of an Arabic version of the Pahlavi translation of Teucer of Babylon.

We do not know so much of the study of astronomy under Shâpûr, though it does seem that Ptolemy's Syntaxis was one of the Greek works translated in this period.[100] It has sometimes been supposed that Shâpûr's foundation at Jundi-Shâpûr included an observatory, but no observations are known to have been made there in pre-Islamic times.[101]

At some point in early Sasanian history, however, an official astronomical work was compiled, the Zîj-i Shâh.[102] This, as we know from Bîrûnî, was revised under Khusrau I (531-579),[103] another ruler who encouraged Greek or Greco-Syrian and Indian scholars in Iran. At present the various versions are known very imperfectly in the citations of the early Islamic astronomers and astrologers; but from these fragments Professor Kennedy has been able to demonstrate that this zîj contains parameters from the ârddharâtrika or Midnight system of Âryabhaṭa, which is the same as that of the Old Sûryasiddhânta of Lâṭadeva and the Khaṇḍakhâdyaka of Brahmagupta. It has also been possible to show that a series of horoscopes of the vernal equinoxes of the first regnal years of the Sasanian kings, probably due to the ninth-century astrologer from Balkh, Abû Ma'shar, was computed by means of the planetary theory of the Old Sûryasiddhânta.[104] Another possible influence which this text may have had is on a Zoroastrian doctrine preserved in the Greater Bundahishn and in the Shikandgûmânîk vijâr. These works state that the planets are bound by chords to the chariot of the sun.[105] Bîrûnî, in his book On Transits, also attributes this theory to the Persians.[106] A similar idea appears in a Manichaean text from Turfan[107] and in the seventh- or eighth-century Mandaean Ginzâ.[108] The modern Sûryasiddhânta, which is known to preserve many of the theories of its similarly named predecessors, explains the anomalies in planetary motion by the activities of demons stationed at the sun, the apogees, and the nodes, who pull the planets along by chords of wind.[109] The Sasanian concept would appear to be a reflection of the Indian. Therefore, either the Old Sûryasiddhânta itself or a very similar text must have been translated into Pahlavi, perhaps under Khusrau.

Sanskrit astrological works were also popular in Iran. The early Islamic

98 MS Add. 23,400 of the British Museum.

99 *Al-Bîrûnî On Transits*, trans. M. Saffouri and A. Ifram with a commentary by E. S. Kennedy, Beirut, 1959, 3: 15 and 5: 10-11.

100 Zaehner, *Zurvan*, p. 139.

101 A. Sayili, *The Observatory in Islam*, Publ. Turkish Historical Soc. 7, 38, Ankara, 1960, pp. 50-51, 357-358.

102 See E. S. Kennedy, " The Sasanian Astronomical Handbook *Zîj-i Shâh* and the Astrological Doctrine of 'Transit' (Mamarr)," *JAOS*, 1958, *78*: 246-262.

103 E. S. Kennedy, *A Survey of Islamic Astronomical Tables, Trans. Amer. Phil. Soc.*, 1956, *NS 46*, pt. 2, p. 130.

104 See D. Pingree, " Historical Horoscopes," to appear in *JAOS*.

105 Zaehner, *Zurvan*, pp. 164, 416-417. The authors of the Pahlavi books appear not to have realized the function of these chords.

106 Bîrûnî On Transits 15: 13-16: 9.

107 Zaehner, *Zurvan*, p. 161 fn. 3.

108 *Ibid.*, p. 160 fn. 1.

109 Sûryasiddhânta 2, 2, ed. K. Chaudhary, Kâśî Sanskrit Series 144, Benares, 1946.

astrologers — many of whom were Persians — incorporated numerous Indian theories into their books, and most of these must have reached them through Pahlavi texts. Of course, there were direct translations from Sanskrit into Arabic made in the eighth century, but these seem to have been mainly of astronomical works, such as the Brâhmasphuṭasiddhânta and the Khaṇḍakhâdyaka of Brahmagupta; Bîrûnî says that in his time no Sanskrit astrological treatises had been translated into Arabic.[110] The Indo-Iranian astrology of these early Islamic authors reached Byzantium at the end of the eighth century in the works of pseudo-Stephanus of Alexandria and of Theophilus of Edessa; more was translated into Greek in the Comnenan period, the late eleventh and twelfth centuries.[111] It arrived in the Latin West in the twelfth and following centuries. These translations are useful because of their preservation of texts which sometimes have been lost in the original Arabic.

The most important of the transmitters of Indo-Iranian astrology was Abû Ma'shar. In his Book of the Thousands, epitomized by al-Sijzî in the late tenth century,[112] he gave a yuga-system of astronomy which he called the Thousands of the Persians. The mean motions of the planets in this system are preserved in Bîrûnî's Book of Instruction in the Elements of the Art of Astrology.[113] The period used is 360,000 years, in the middle of which — on 17 February -3101 — occurred the mean conjunction of the planets at Aries 0°, which, for the Indians, marks the beginning of kaliyuga; Abû Ma'shar interprets it as the indicator of the Flood.

To date the Flood in -3101 is rather strange. But one is not at a loss to explain it. In his Book of Conjunctions Abû Ma'shar says that this date was proposed by someone whose name, corruptly preserved in Arabic, may be Abydenus.[114] Abydenus, it may be remembered, was one of those Greek historians who placed the Babylonian kingdom of 432,000 years' duration before the Flood; and this 432,000 years is the length of the kaliyuga which begins in -3101. Someone aware of both Abydenus' Flood story and the astronomical date of the beginning of kaliyuga has rather sloppily combined the two traditions. As Bîrûnî remarks, the Persians did not usually believe in the Flood; but there were some who did accept it, confining its effectiveness to western Asia.[115] It is surely these Persians whom one must suspect of dating the Flood in -3101, for they occupied the ground, quite literally, between the two ideas which were synthesized. This interpretation agrees with Bîrûnî's statement in the India that Abû Ma'shar's date for the Flood was derived from the Hindu kalpa-theory.[116]

[110] India, vol. 2, p. 211.

[111] For pseudo-Stephanus, see my paper cited in fn. 104. Theophilus, Apomasar (Abû Ma'shar), and Achmat, whose works are filled with Indian material, are in the process of being edited.

[112] The manuscript was discovered by Professor Kennedy, to whom I owe much of what I know of Arabic astronomy and astrology.

[113] Ed. and trans. R. R. Wright, London, 1934, pp. 113-114.

[114] This information is from a translation by E. S. Kennedy; the identification with Abydenus was originally suggested by Professor A. J. Sachs of Brown University.

[115] *The Chronology of Ancient Nations*, trans. C. E. Sachau, London, 1879, p. 27.

[116] India, vol. 1, p. 325.

In any case, -3101 cannot be a Greek date for the Flood. The only known astrological Flood-theory in Greece is that derived from Berossos' Babyloniaka, according to which a conjunction of all the planets in Cancer produces an ecpyrosis, or conflagration, whereas a conjunction in Capricorn causes a kataklysmos, or flood.[117] The choice of Cancer and Capricorn is clearly due to a desire to connect the world-year with the summer and winter solstices. In this tradition the Aries conjunction of -3101 is meaningless.

But it is also contrary to astrological theory. The zodiac is divided into four triplicities, which are connected with the four elements. The first consists of Aries, Leo, and Sagittarius, and is fiery; the second of Taurus, Virgo, and Capricorn, and is earthy; the third of Gemini, Libra, and Aquarius, and is airy; and the last of Cancer, Scorpio, and Pisces, and is watery. The conjunction of -3101 occurs in a fiery triplicity and astrologically must indicate, if anything, a conflagration, not a flood. The latter can take place only when there is a conjunction in a watery triplicity. This was recognized by Abû Ma'shar's predecessor, Mâshâ'allâh, who dated the Flood in -3300 [118] because in that year occurred a Saturn-Jupiter conjunction in Cancer, the first sign of the watery triplicity; and Mâshâ'allâh expressly states that he is using the Zîj-i Shâh. Cancer is also connected with the Flood in the Pahlavi Bundahishn.[119]

As has been said before, Abû Ma'shar's yuga is 360,000 years split in half by the Flood; in other words, the 180,000 years of the original Old Sûryasiddhânta. In fact, the parameters which Abû Ma'shar gives for the moon, Mars, Venus, and Mercury — if one corrects the last by one — are exactly one-twelfth of those in the Old Sûryasiddhânta of Lâṭadeva. But the parameter for Saturn is one-twelfth of that in the Somasiddhânta, the Brahmasiddhânta of the Śâkalyasaṃhitâ, the Vṛddhavasiṣṭhasiddhânta, and the modern Sûryasiddhânta; and that for Jupiter is one-twelfth of what appears in the Âryabhaṭîya.[120] Therefore, the so-called Thousands of the Persians is really an eclectic Indian system. Abû Ma'shar, of course, probably found it in some Pahlavi text or Arabic translation thereof; but I think its ultimate origin is now clear. In the On Transits, Bîrûnî recognizes that the equations in Abû Ma'shar's zîj were taken from the Zîj-i Shâh, which had got them from an Indian source.[121]

That Abû Ma'shar is extremely unreliable in what he reports, moreover, can easily be shown from a statement of his which Bîrûnî has preserved in his Chronology of the Ancient Nations.[122] There he asserts that, using the system of the Persians, he has found that the planets are not in mean conjunction at Aries 0° at the time of the vernal equinox of -3101, but are scattered between Pisces 27° and Aries 1°. Abû Ma'shar is convicted of

117 Fr. 37, pp. 266-267 Schnabel.

118 See my paper cited in fn. 104.

119 Bundahishn 7, 1-5, pp. 25-26 West.

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	Old Sûryasiddhânta	Âryabhaṭîya	Brahmasiddhânta	Abû Ma'shar
Saturn	146,564	146,564	*146,568*	12,214
Jupiter	364,220	*364,224*	364,220	30,352
Mars	*2,296,824*	*2,296,824*	2,296,832	191,402
Venus	*7,022,388*	*7,022,388*	7,022,376	585,199
Mercury	*17,937,000*	17,937,020	17,937,060	1,494,751 (1,494,750)
Moon	*57,753,336*	*57,753,336*	*57,753,336*	4,812,778

121 On Transits 30: 10-16.

122 Chronology, p. 29.

lying by one glance at the parameters of his Thousands of the Persians. Those for the superior planets and the sun are all divisible by two, and as the conjunction of -3101 took place exactly in the middle of the yuga of 360,000 years, they must all be at Aries 0° at that date; the mean positions of the inferior planets, of course, are identical with the mean sun. So Abû Ma'shar's statement is nonsense when referred to his Persian system; but its source, fortunately, is known. In the kalpa-system of the Brâhmasphuṭa-siddhânta the mean planets are precisely between the limits set by Abû Ma'shar at the beginning of kaliyuga. This fact was not unnoticed by the Indians; it is recorded in the Siddhântaśekhara of the eleventh-century Śrîpati.[123] It must have been part of the polemic addressed by the partisans of the mahâyuga against those who preferred the kalpa. Abû Ma'shar has stupidly used it as a criticism of a system for which it is totally irrelevant.

So far nothing original has turned up in Sasanian astronomy and astrology, save for the fact that they synthesized Greek and Indian theories. However, we do know of one concept which seems definitely to be an Iranian innovation. This is the theory that history is the unfolding of the influences of periodically recurring Saturn-Jupiter conjunctions.[124]

Roughly, the idea behind astrological history is this. A Saturn-Jupiter conjunction takes place about every 20 years; a series will occur in the signs of one triplicity for about 240 years, that is twelve conjunctions; and they will have passed through the four triplicities and begin the cycle again after about 960 years. When they shift from one triplicity to another, they indicate events on the order of dynastic changes. The completion of a cycle of 960 years, which is mixed up with various millennial theories, causes revolutionary events such as the appearance of a major prophet. The ordinary course of politics is dependent on the horoscopes of the vernal equinoxes of the years in which the minor conjunctions within a triplicity take place.

The tenth-century astrologer Ibn Hibintâ preserves fragments of an astrological history written on this principle by Mâshâ'allâh, and a Parisian manuscript of a compilation by al-Sijzî contains the horoscopes, but not the interpretations, for such a history written under Hârûn al-Rashîd. Al-Kindî and Abû Ma'shar also wrote on these conjunctions, as did pseudo-Stephanus of Alexandria in Greek.

A non-Greek doctrine such as that of the Saturn-Jupiter conjunctions, occurring in the works of the early Islamic astrologers, may be assumed to have an Iranian origin. But there is more substantial evidence of the theory's Sasanian background; Ibn Khaldun says that Khusrau's famous minister, Buzurjmihr, was familiar with the method, and he cites from Jirâsh as an authority on the subject an astrologer with the obviously Iranian name of Hurmuzdâfrîd.

Astrological history by Saturn-Jupiter conjunctions, then, is the main,

123 Siddhântaśekhara 2, 52-53, ed. Babuâji Miśra, 2 pts., Calcutta, 1932-1947.

124 See my paper cited in fn. 104, where the subject is dealt with more extensively and the appropriate references will be found.

if not the only, Sasanian contribution to astronomy or astrology. Since, through the conjunction of -3101, it is closely linked with the yuga-system of astronomy, one would expect that any astronomer who learned the latter from the Sasanians would also have learned the former. But there is not a trace of the knowledge of these conjunctions in India. This I take to be fairly conclusive evidence that Indian yuga-astronomy could not have been borrowed from Iran, but instead profoundly influenced Sasanian science.

Appendix 1

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